Laser-Based Coatings Removal

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Abstract

Research sponsored by the U.S. Department of Energy's Federal Energy Technology Center under contract DE-AR21-94MC30359 with F2 Associates, Inc., 14800 Central SE, Albuquerque, New Mexico 87123; Telefax: 505-271-1437; E-mail: F2Assoc@aol.com. The COR is David L. Schwartz and the period of performance is 13 June 1994 through 31 March 1998.

Laser-based coatings removal can provide significant advantages over other methods for removal coatings, such as lead-based paint, especially in terms of waste reduction, no substrate damage, prompt collection of the debris, no liquid or chemicals, and minimal worker protection requirements. The objective of F2's contract with DOE FETC is to develop and test a laser-based technology for removing contaminated paint and other contaminants from concrete and metal surfaces. The status of this effort and the demonstrations and laboratory tests that are planned during the next four months are described, along with the current efforts and successes in commercializing this technology for a variety of applications.

The presentation describes the four basic types of laser-based decoating systems developed by F2: (1) small parts decoating unit, (2) large parts decoating system, (3) mobile robotic decoating system, and (4) hand-held decoating system. Photographs and video clips of the systems and components are interspersed through the presentation. These four product lines integrate the results of several DOE-funded activities, including the FETC contract, the development of Rosie Robot by RedZone Robotics, the development of a spectral sensor by PSI under DOE funding (including contributions by Los Alamos National Laboratory), the cost/benefit models being developed by the EERC at the University of North Dakota, and the development of the large parts decoating system funded through SERDP, which includes the DoD, EPA and DOE.

In addition to maintenance and decommissioning applications for the DOE, commercial applications of the laser-based decoating include maintenance and decommissioning at nuclear power plants, precision coatings removal as part of the manufacturing process in a variety of industries such as automotive and medical equipment, the decoating and depainting of aircraft parts and airframes, the depainting of large structures such as brides and storage tanks, the depainting of various vehicles such as boats and trains. F2 has started to tap these commercial markets and plans to greatly increase their efforts at commercialization over the next year.

EM133

Laser Based Coatings Removal

by

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A small, high-tech business focused on environmentally friendly laser-based decoating systems

Presented at

"Industry Partnerships to Deploy Environmental Technology"

21-23 Oct 97 @ DOE FETC-Morgantown

David Schwartz, COR, DOE FETC-Pittsburgh

Steve Bossart, Manager, DOE FETC-Morgantown

F2 Associates Inc.

Example of a Coatings Removal Technology Matrix

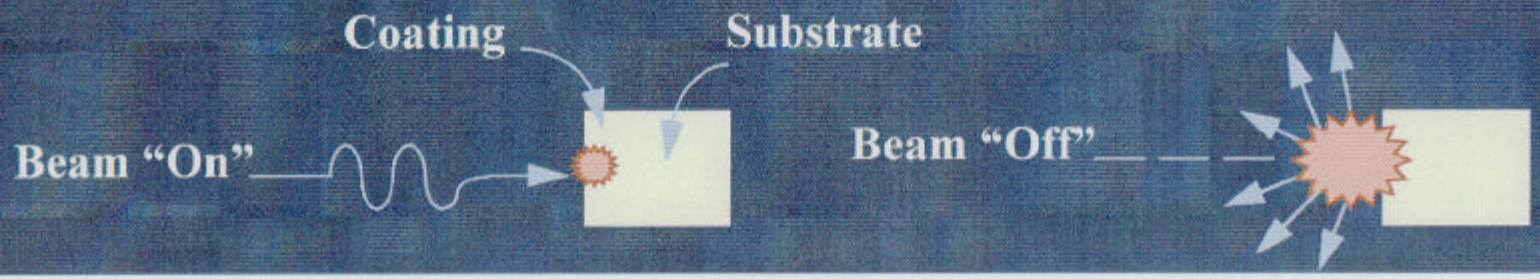
	Decrease waste volume	Cleans out surface pores	No thermal damage	No mechanical damage	No hazardous chemicals	No liquids	Level-D dress
Mechanical Scabbling	Same		√		√	√	?
Solid abrasives or air blasting	Increase		√		√	√	?
CO_2 ice pellet blasting	Same		√	√	√	√	CO_2 atmos
Water blasting	Increase		√				
Liquid nitrogen cryofacture	Same		?	√	√	√	N_2 atmos
Wet chemical strippers	Increase		√	√			?
Dry strippable coatings	Increase		√	√		√	?
Continuous wave lasers	Same	√			√	√	√
Pulse-repetition lasers	Decrease	√		√	√	√	√

Laser Ablation: DOE D&D National Needs Analysis

- Laser ablation is a technology that offers a potential solution to 7 of the 31 Decontamination and Decommissioning National Needs identified:
  - **#2 Decontamination on contaminated metal**
  - **#5 Material recycle**
  - **#6 Decontamination on contaminated concrete**
  - **#10 Decontamination of large/complex equipment and structures**
  - **#21 Decontamination of lead**
  - **#29 Decontamination of graphite reactor components**
  - **#31 Characterization and decontamination of construction debris (Chromium)**
- In addition, F2's on-line sensor technology will help to address:
  - **#4 Characterization of contaminated surfaces**
  - **#26 Characterization data management**

Coatings Removal with Pulsed Lasers

- Lasing time pulse width must be "just right"
  - If too short, then little stripping
  - If too long, then excessive substrate heating
- Dwell time must be "just right"
  - If too short, then there is interference between the next pulse and the debris cloud from the last pulse
  - If too long, the process is slow



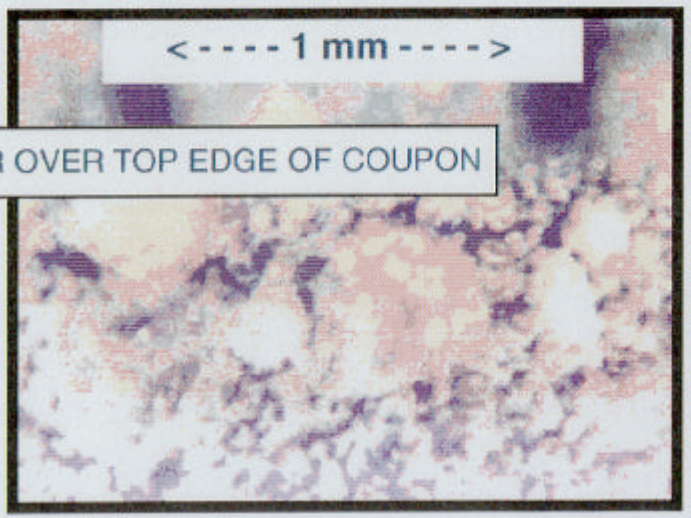
Phase-I
Strip-Test Microphotograph

REFERENCE
CONCRETE COUPON
7.75 cm x 7.75 cm x 3.8 cm thick
TROWELED SMOOTH SURFACE
(Typical of a concrete floor);
NO OTHER COATING

No Ablated Material Capture/Suction Nozzle Used

Microphoto Before Removing Troweled Surface

Microphoto After Laser Ablation of Troweled Surface

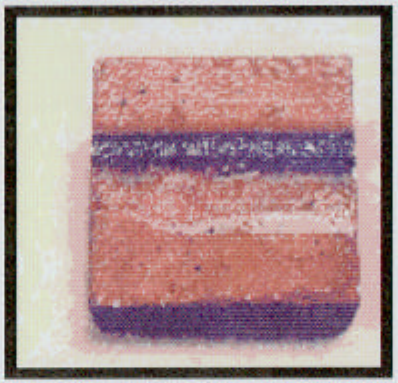


HASH MARKS VIA CLEAR PLASTIC RULER OVER TOP EDGE OF COUPON

Concrete reference sample before applying coatings

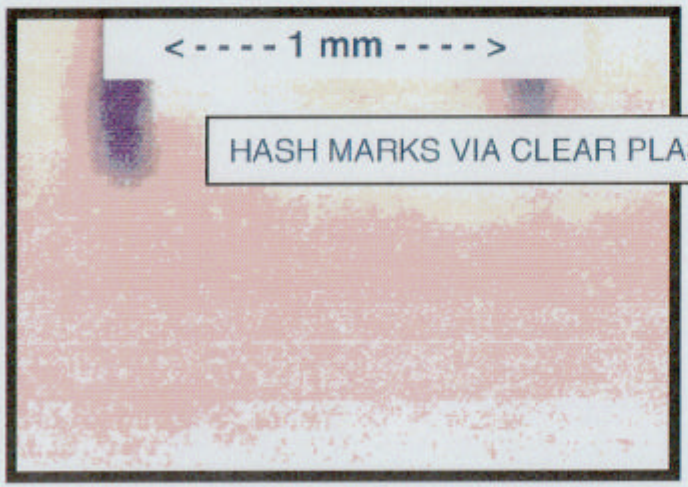
Phase-I
Strip-Test Microphotograph

REFERENCE
CONCRETE COUPON
7.75 cm x 7.75 cm x 3.8 cm thick
TROWELED SMOOTH SURFACE
Plus 4 mils Overcoat of
RED LEAD PRIMER

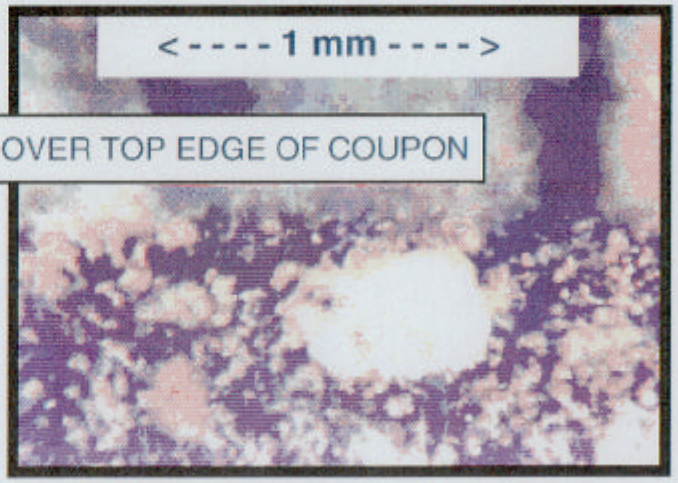


Edge Deposits Due to Insufficient Pump Speed for Capture/Suction Nozzle
(to be corrected in Phase-II)

Microphoto Before Removing Coating & Troweled Surface



Microphoto After Laser Ablation of Coating & Troweled Surface



HASH MARKS VIA CLEAR PLASTIC RULER OVER TOP EDGE OF COUPON

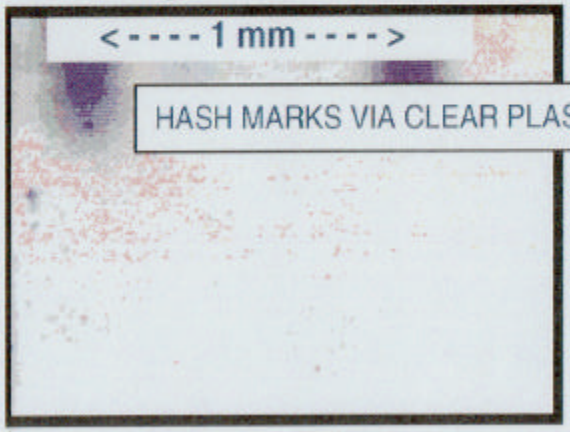
Concrete reference coated with red lead primer and then laser ablated

Phase-I
Strip-Test Microphotograph

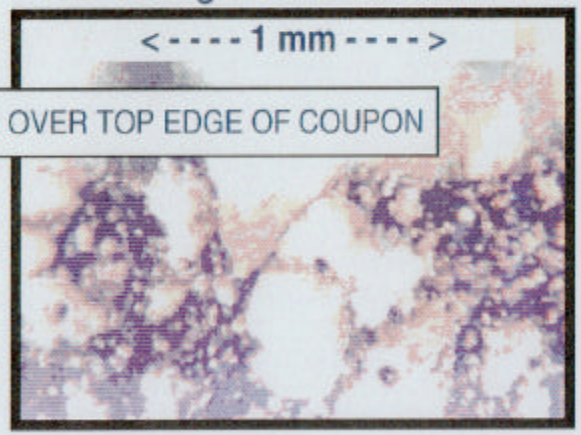
REFERENCE
CONCRETE COUPON
7.75 cm x 7.75 cm x 3.8 cm thick
TROWELED SMOOTH SURFACE
Plus 10 mils White (reflecting)
Overcoat of 2-PART EPOXY

Edge Deposits Due to Insufficient Pump Speed for Capture/SuctionNozzle
(to be corrected in Phase-II)

Microphoto Before Removing Coating & Troweled Surface



Microphoto After Laser Ablation of Coating & Troweled Surface

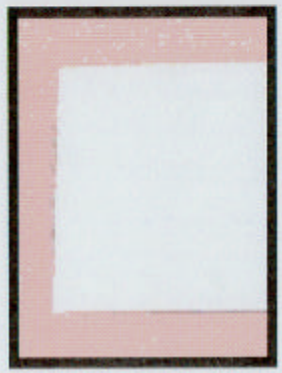


HASH MARKS VIA CLEAR PLASTIC RULER OVER TOP EDGE OF COUPON

Concrete coated with two-part epoxy and then laser ablated.

Phase-I
Strip-Test Microphotograph

Raw Stock 6061T6 cleaned Bare Aluminum Coupon 7.75 cm x 7.75 cm



Sand Blasted Bare Aluminum, to Enhance Paint Adhesion

Raw Stock Microphoto

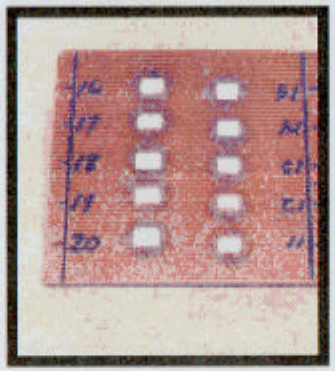
Microphoto After Sand Blasting
Light Spots = 'Craters'

HASH MARKS VIA CLEAR PLASTIC RULER OVER TOP EDGE OF COUPON

Bare aluminum and cleaned aluminum coupons before painting.

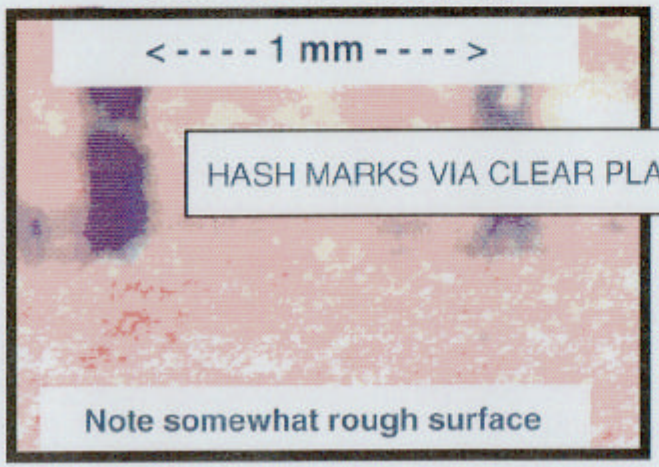
Phase-I
Strip-Test Microphotograph

REFERENCE
ALUMINUM Painted with 4 mils of Red Lead Primer. 10 LaserSpots/Coupon, each ~5mm x 6 mm.



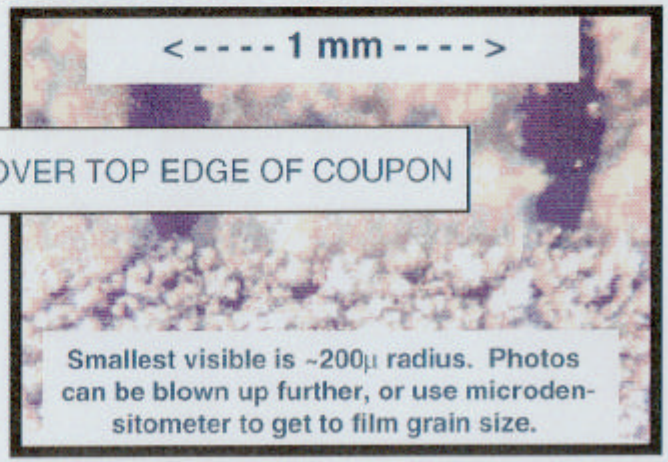
Each Coupon was Used for 10 Tests in the "Burn Thru" Series to Determine J/cm² for the Type of Paint and Thickness.

Microphoto After Painting but Before Laser Stripping



Note somewhat rough surface

Microphoto After Laser Stripping of Paint to Bare Metal. Light Spots = 'Craters'



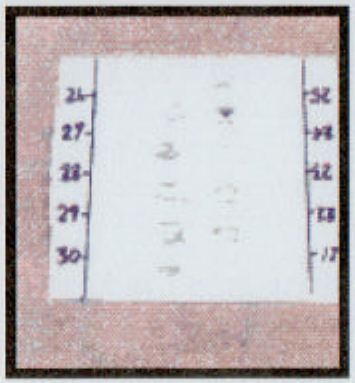
Smallest visible is ~200μ radius. Photos can be blown up further, or use microdensitometer to get to film grain size.

HASH MARKS VIA CLEAR PLASTIC RULER OVER TOP EDGE OF COUPON

Aluminum coupons with red-lead primer paint.

Phase-I
Strip-Test Microphotograph

REFERENCE
CLEANED ALUMINUM PAINTED
with10 mils of 2-part Epoxy
10 Laser Spots/Coupon,
each ~5 mm x 6 mm.



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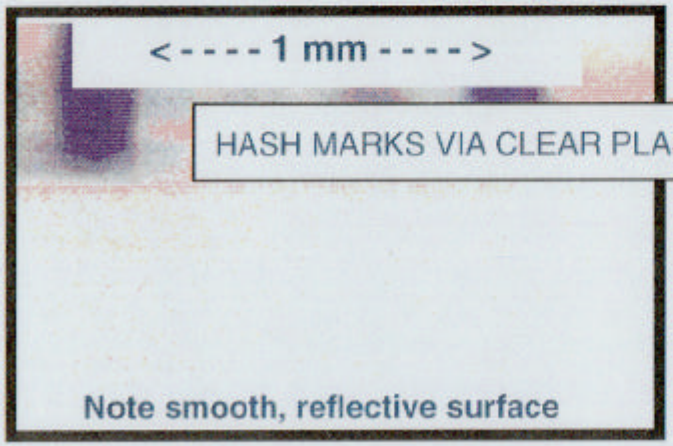
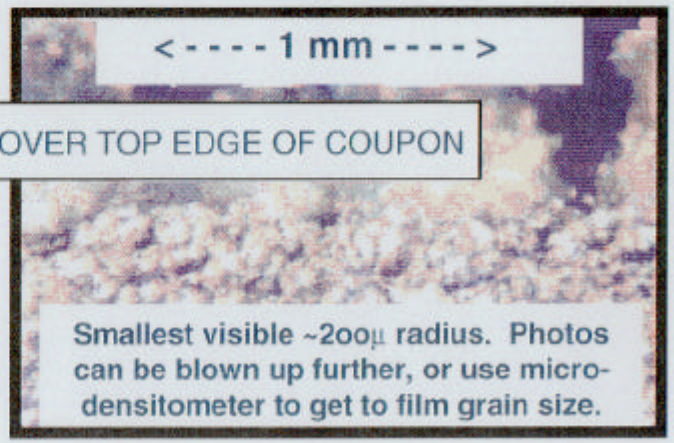
Microphoto After Painting but Before Laser Stripping



Note smooth, reflective surface

Microphoto After Laser Stripping of Paint to Bare Metal. Light Spots = 'Craters'



Smallest visible ~2ooμ radius. Photos can be blown up further, or use micro-densitometer to get to film grain size.

HASH MARKS VIA CLEAR PLASTIC RULER OVER TOP EDGE OF COUPON

Aluminum coupons with two-part epoxy paint.

Types of Decoating Systems

There are four basic types to cover decoating needs:

Type	F2's Funding
I. Small Parts Decoating *Bring the parts to the decoating cell*	DOE Ø-1, SERDP/USAF, and F2
II. Large Parts, Robotic *Bring the parts to the decoating*	SERDP/USAF (DoD, EPA, DOE)
III. Mobile Robotic *Take the system to the items*	DOE Ø-2
IV. Hand-held Workheads *Take the system to the items*	F2, + DOE Ø-2 (testing)

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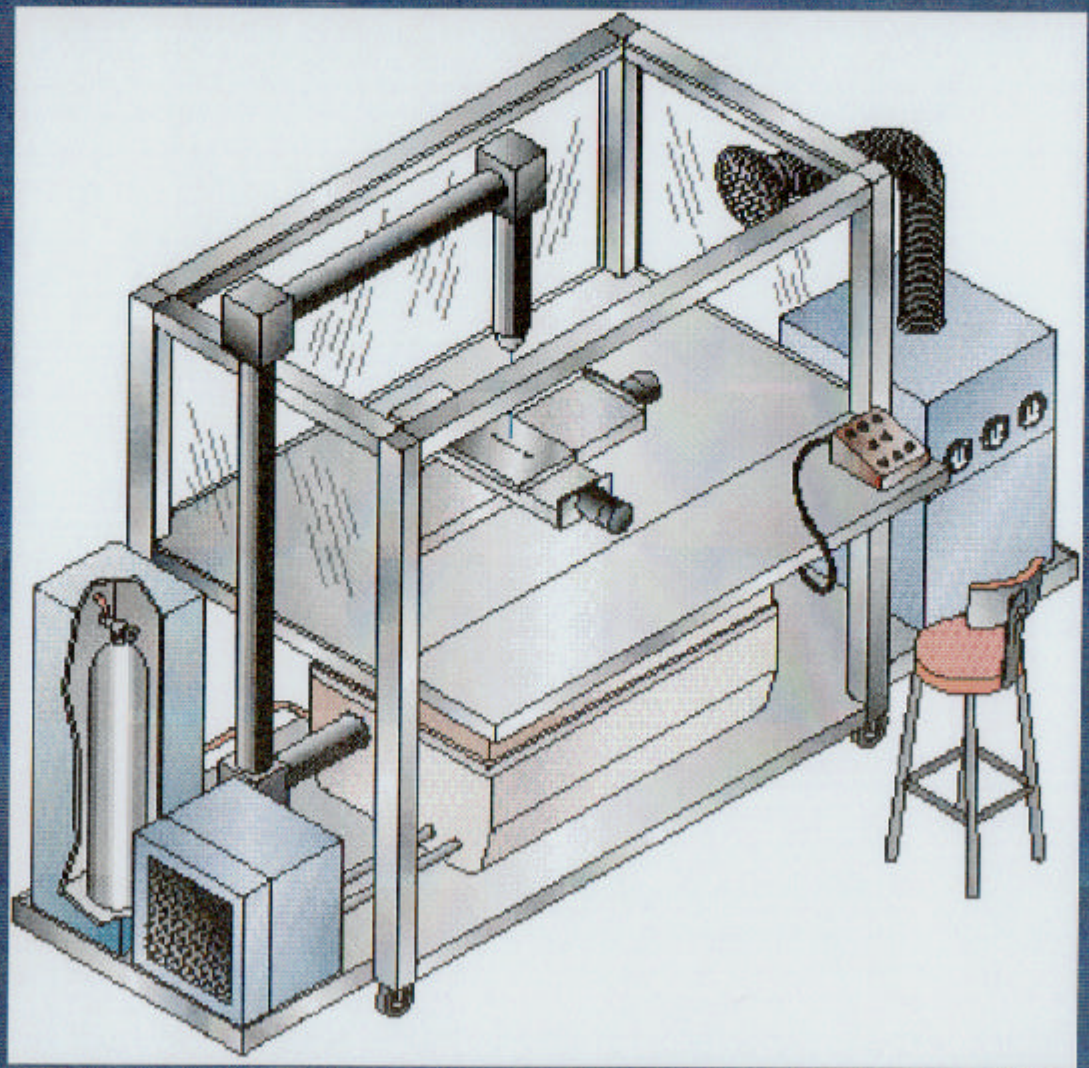
Small Parts Depainting Cell



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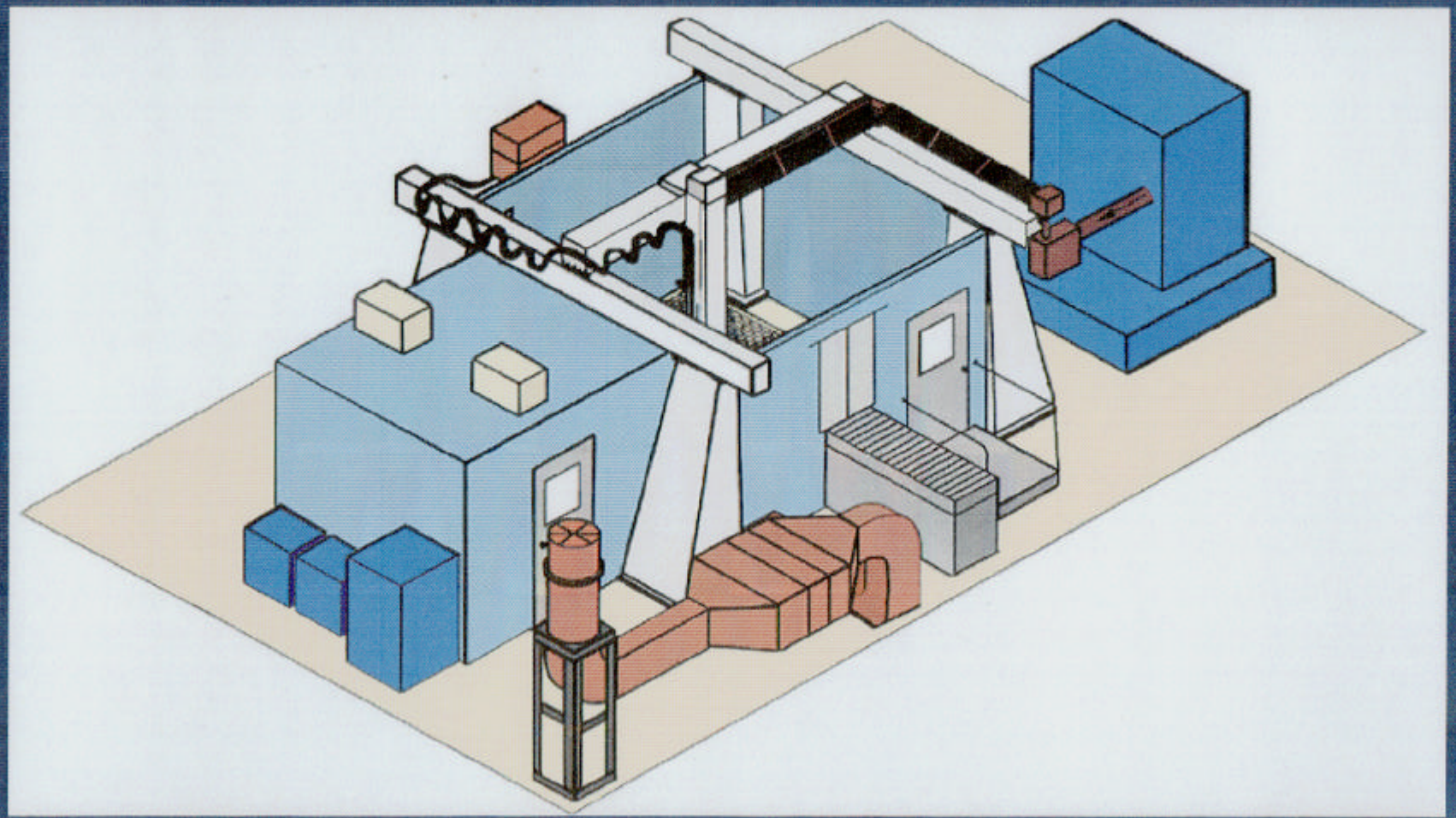
Large Part Cleaning Cell (LCCRS)



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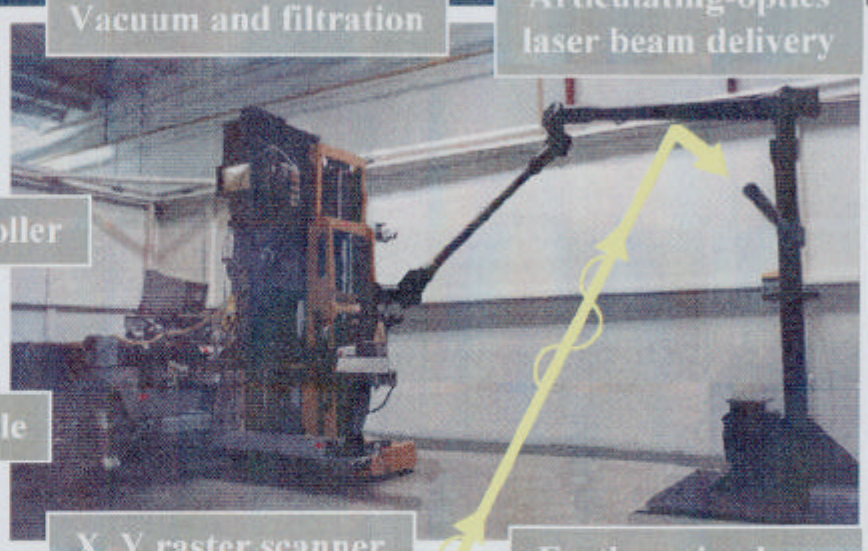
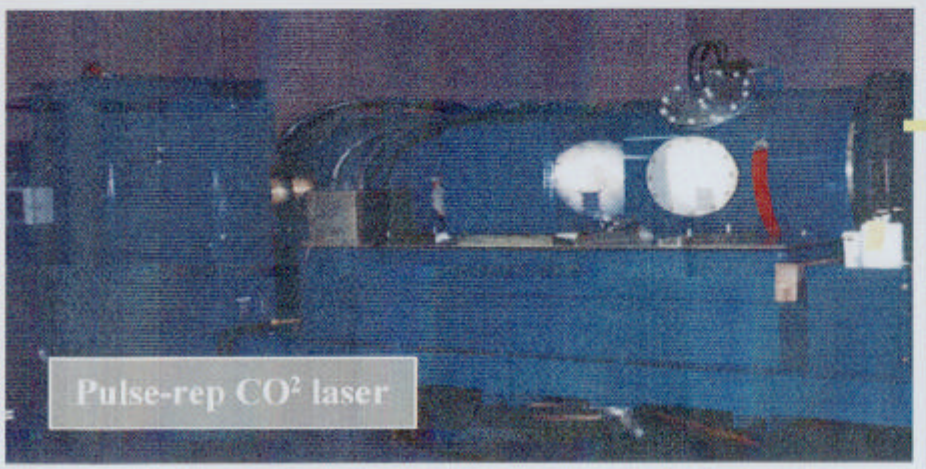
Laser-Based Surface Cleaning Prototype Full-Scale System

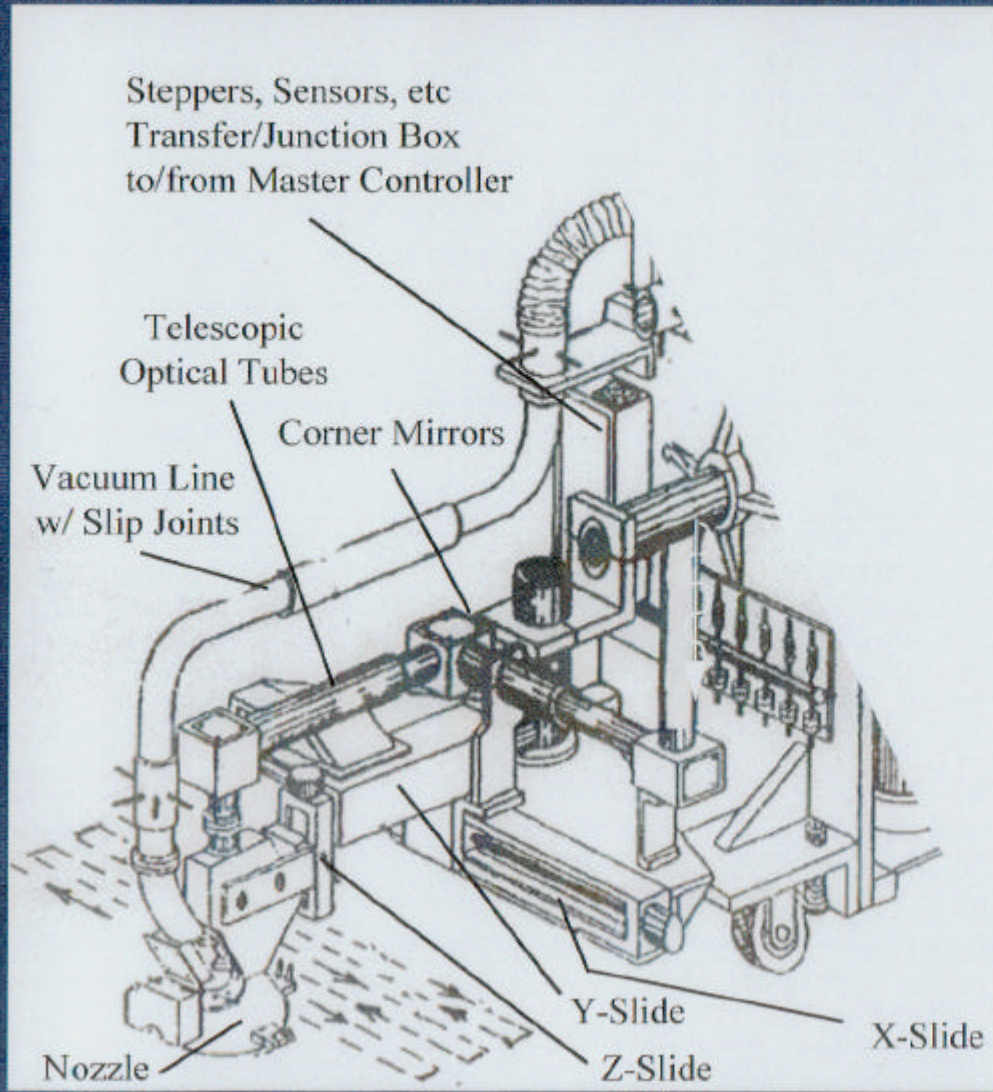
Mount on-line rad and spectral sensors on scanning capture nozzle

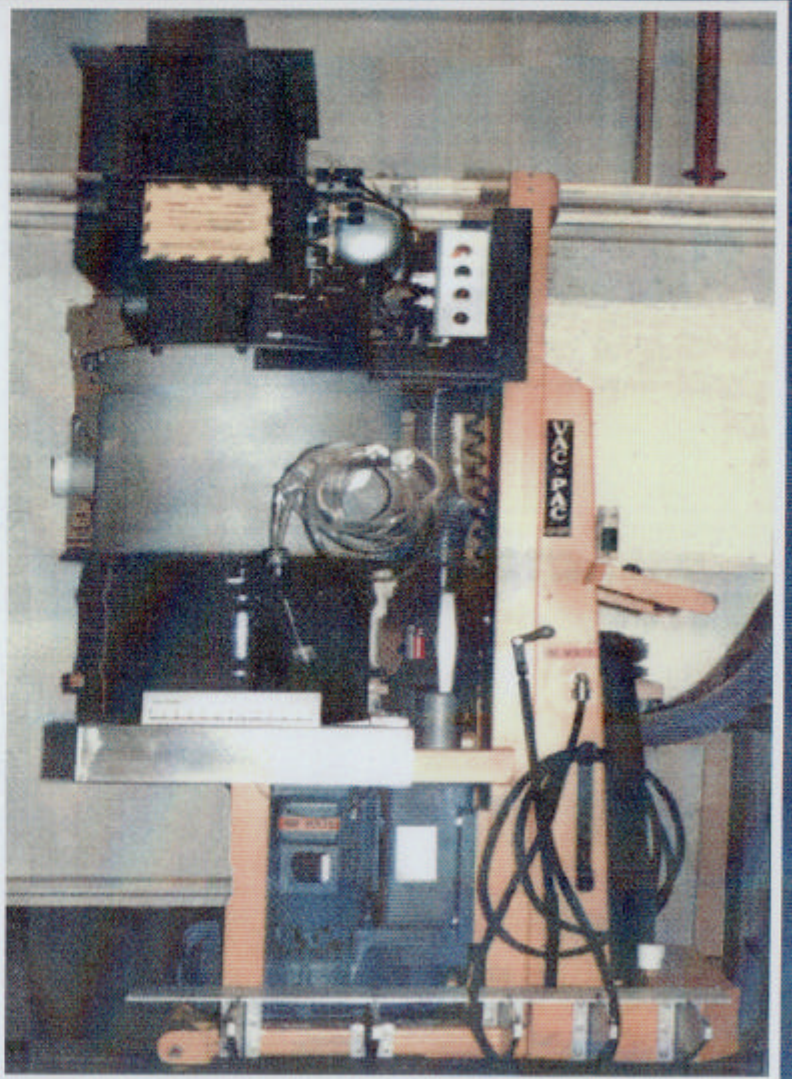




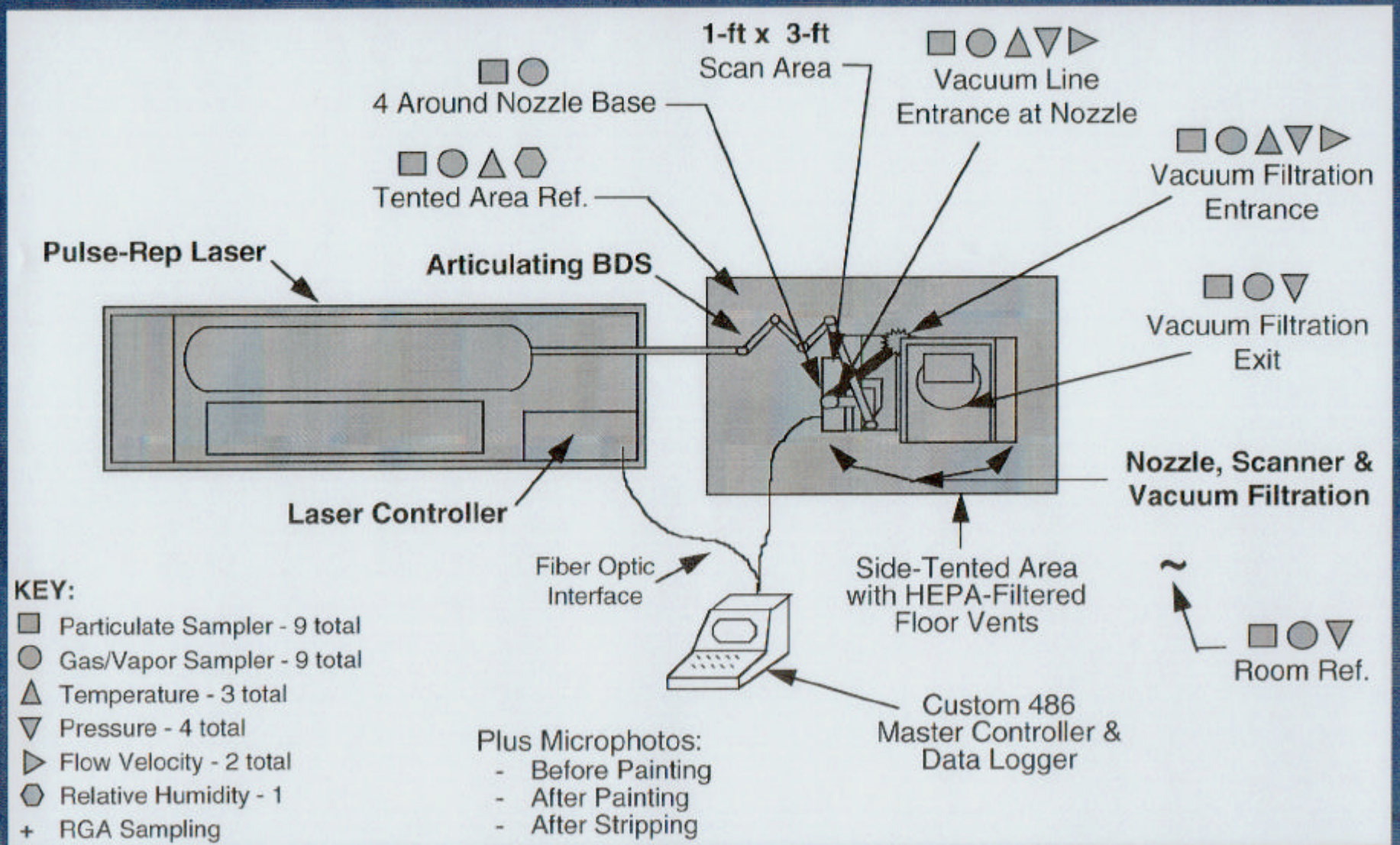
- On-line real-time feedback and control of scan rate and laser pulse rate
- May also lead to on-line assay capability as material is being ablated and deposited into on-line final disposal drum.

Nozzle, Scanner, & Filtration Assembly

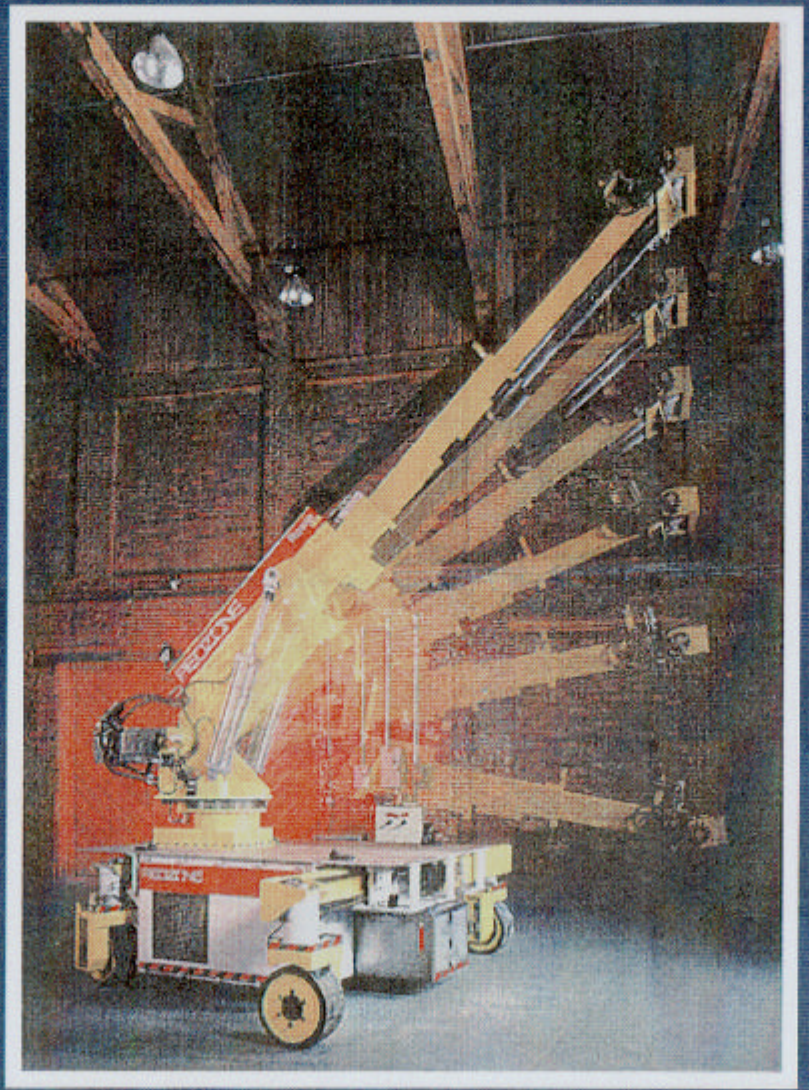




Ø-II Test Layout, Instrumentation & Controls



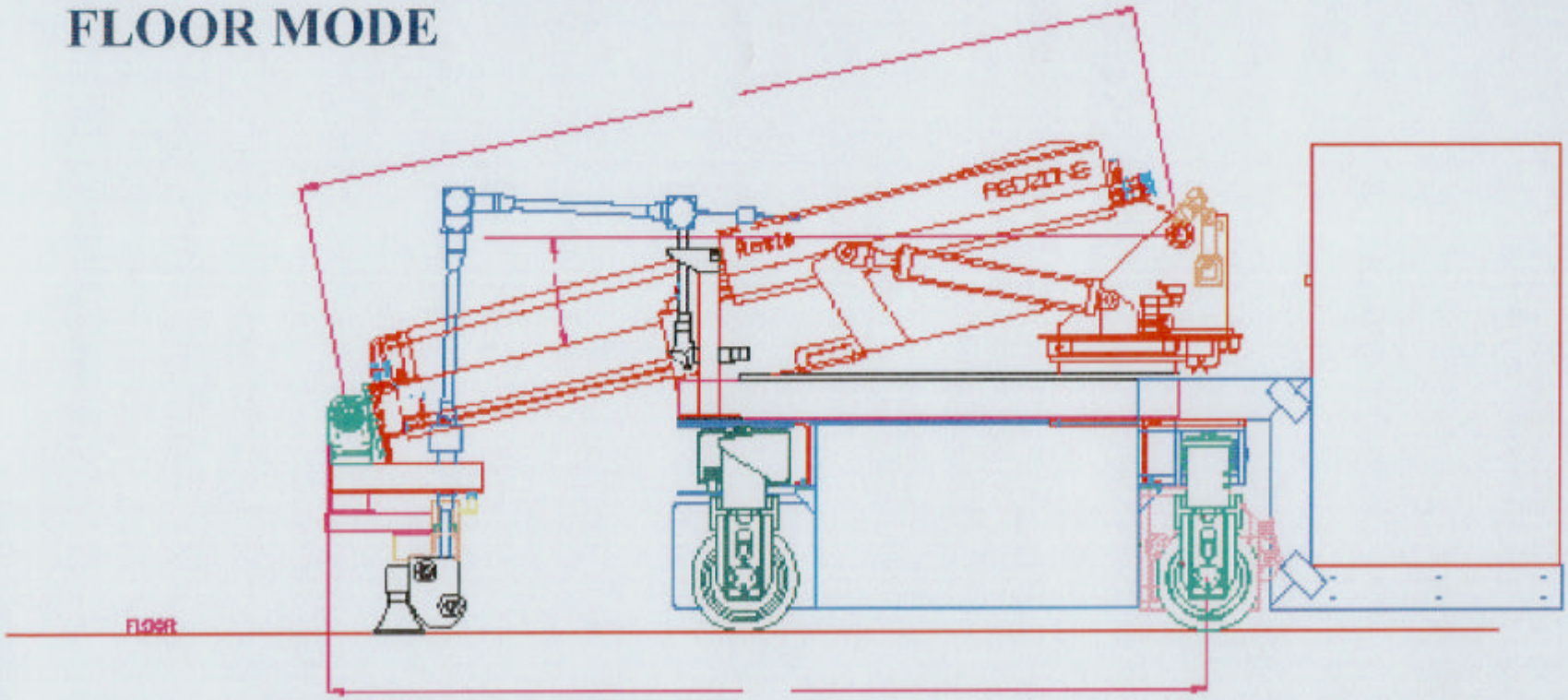
Rosie



Mobile Robotic System Demonstration (DOE Ø-2, Task 4)

System to be demonstrated at X-Change '97, Miami, FL, December 1997

FLOOR MODE



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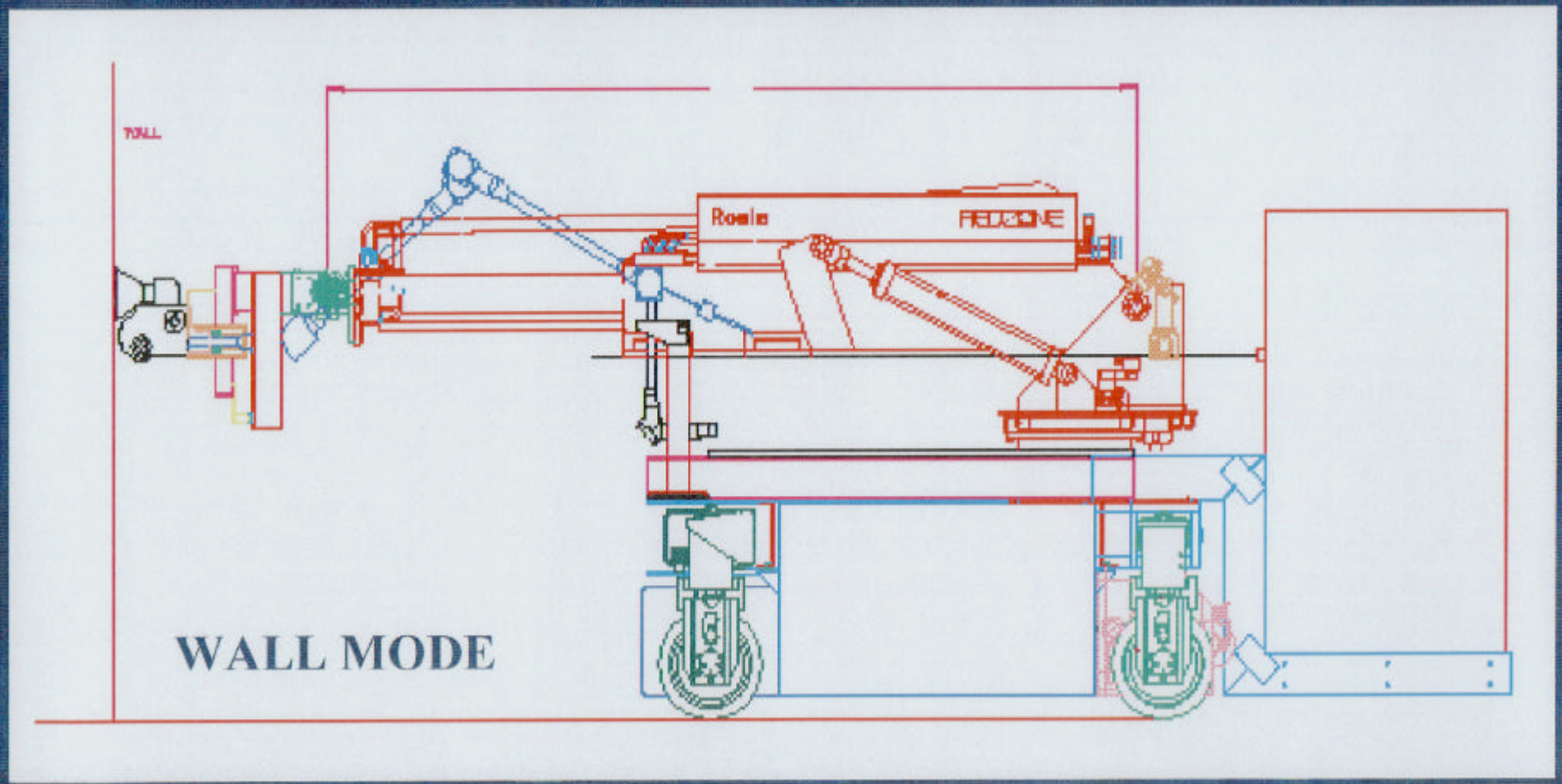

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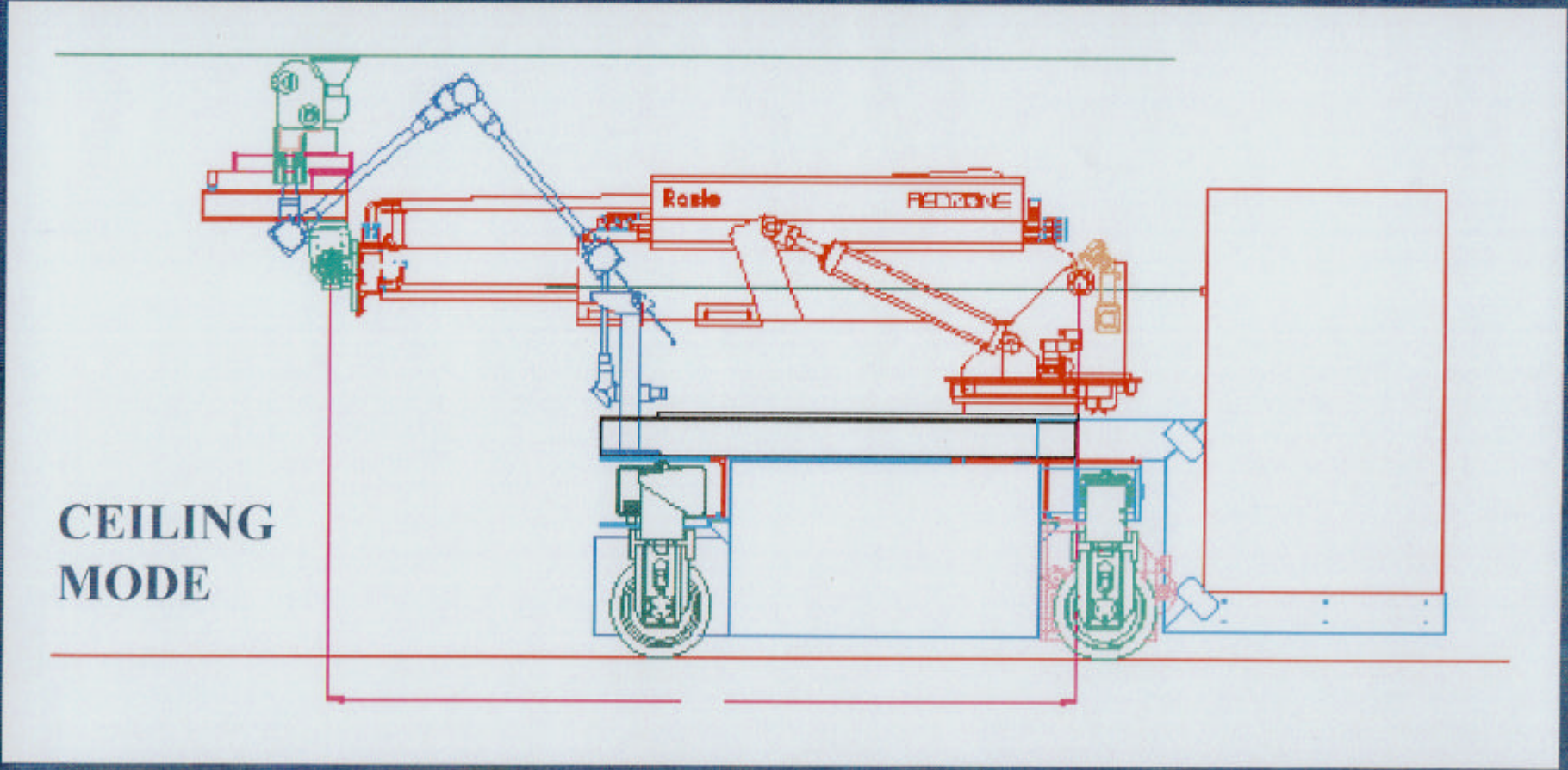
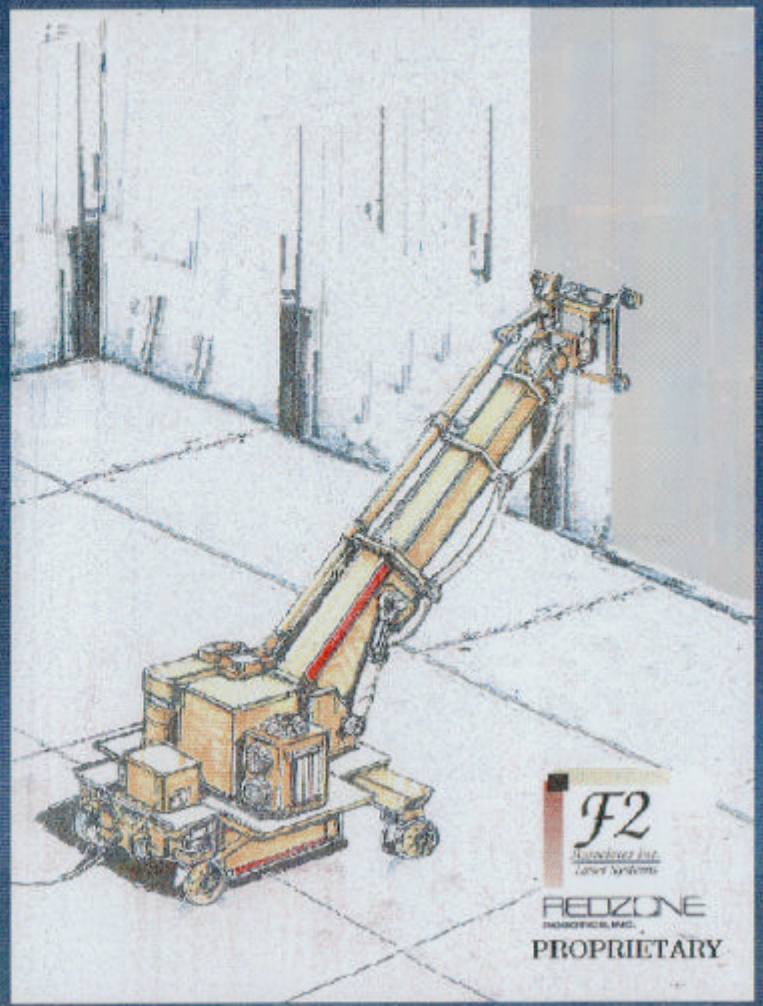


Transition to ROSIE Robot for Wall Cleaning

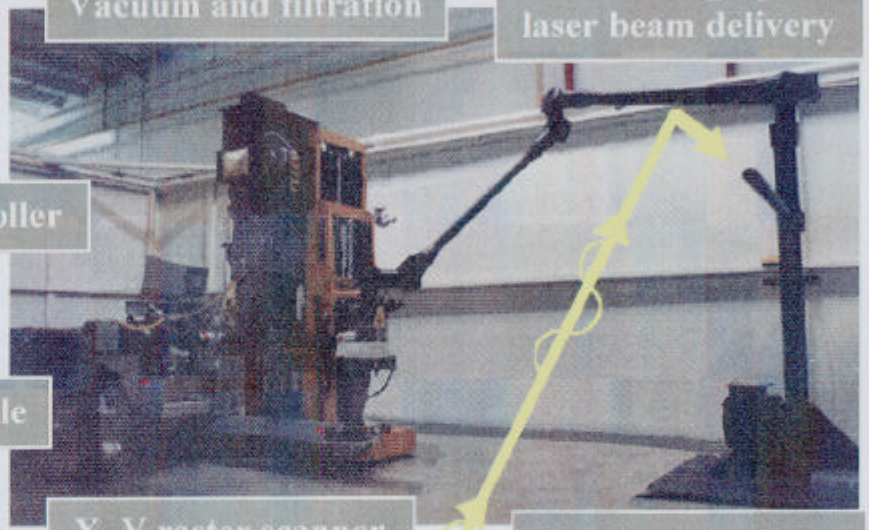
- Remove ROSIE's 7-axis dual-arm end effector and replace with laser nozzle/ scanner unit
- Mount 23-gal VAC-PAC at base of ROSIE's boom
- Fit boom with telescopic and articulating optics
- Connect in laser beam delivery system from remote laser at base of ROSIE's boom

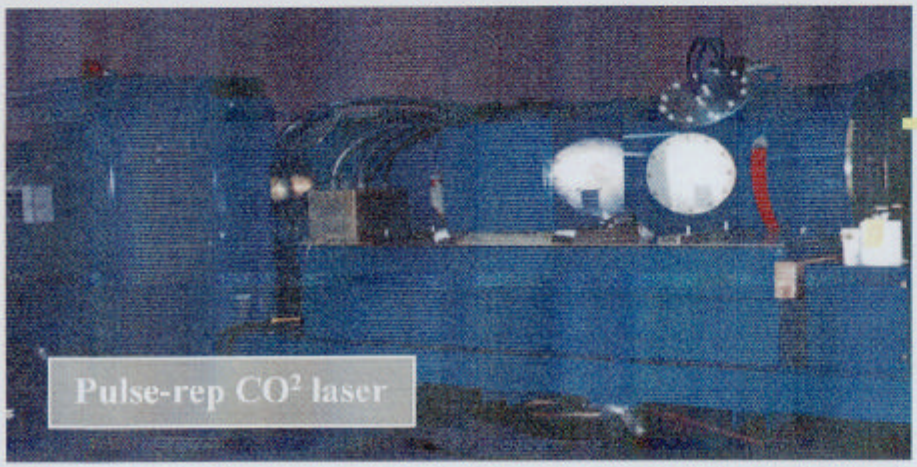


Laser-Based Surface Cleaning Prototype Full-Scale System

F2 Associates Inc.

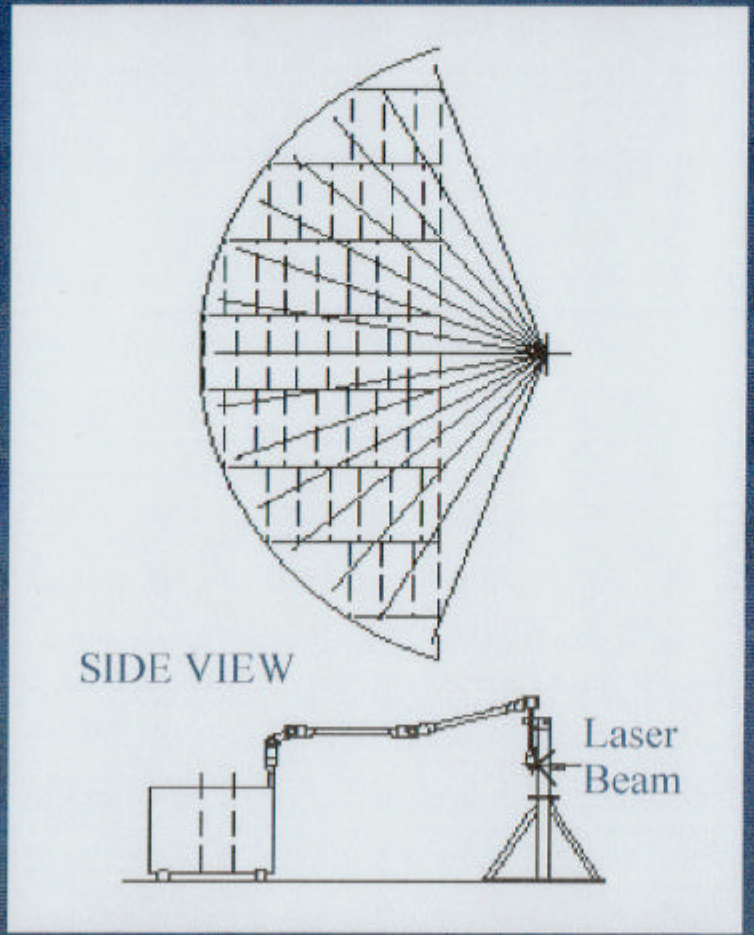
Mount on-line rad and spectral sensors on scanning capture nozzle





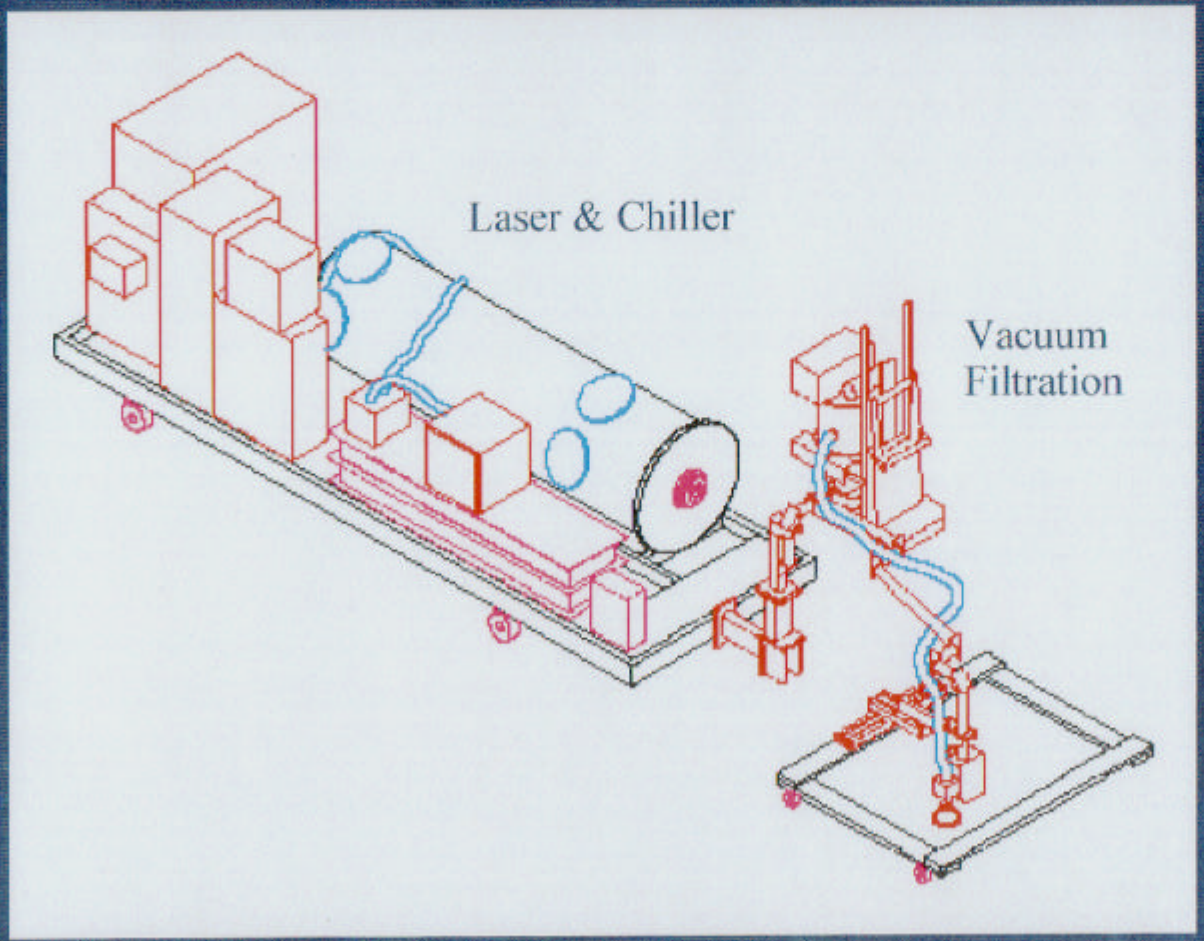
- On-line real-time feedback and control of scan rate and laser pulse rate
- May also lead to on-line assay capability as material is being ablated and deposited into on-line final disposal drum.

Simple Configuration Covers ~150 sq-ft without Moving Laser



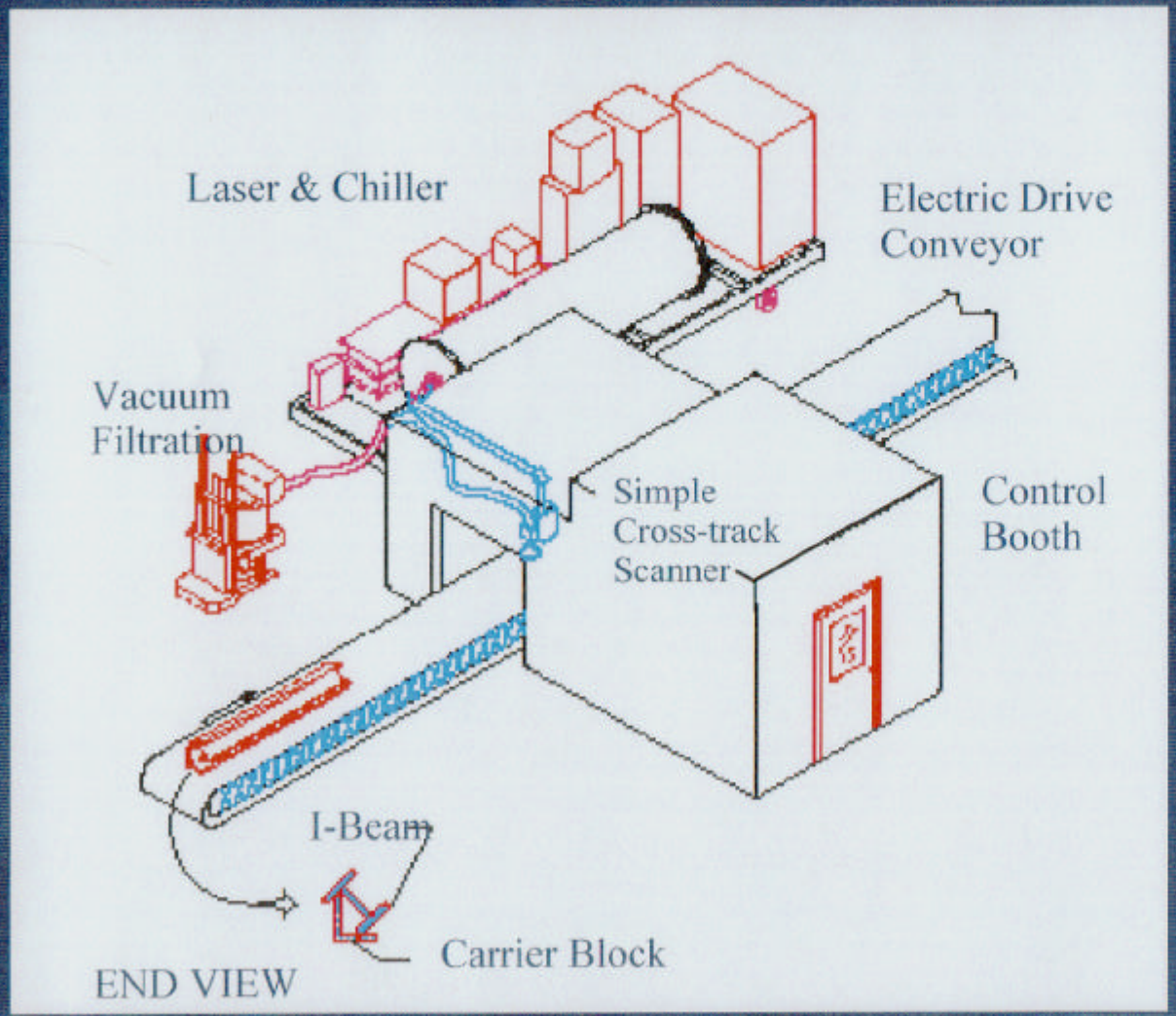
Top view showing numerous scanner rectangles

Simple Configuration for Decoating Horizontal Surfaces



X,Y Scanner with Capture Nozzle Mounted in Roll-Around Holder

I-Beam Cleaning Concept Sketch



Envision a slightly different version for decoating the outside of pipe

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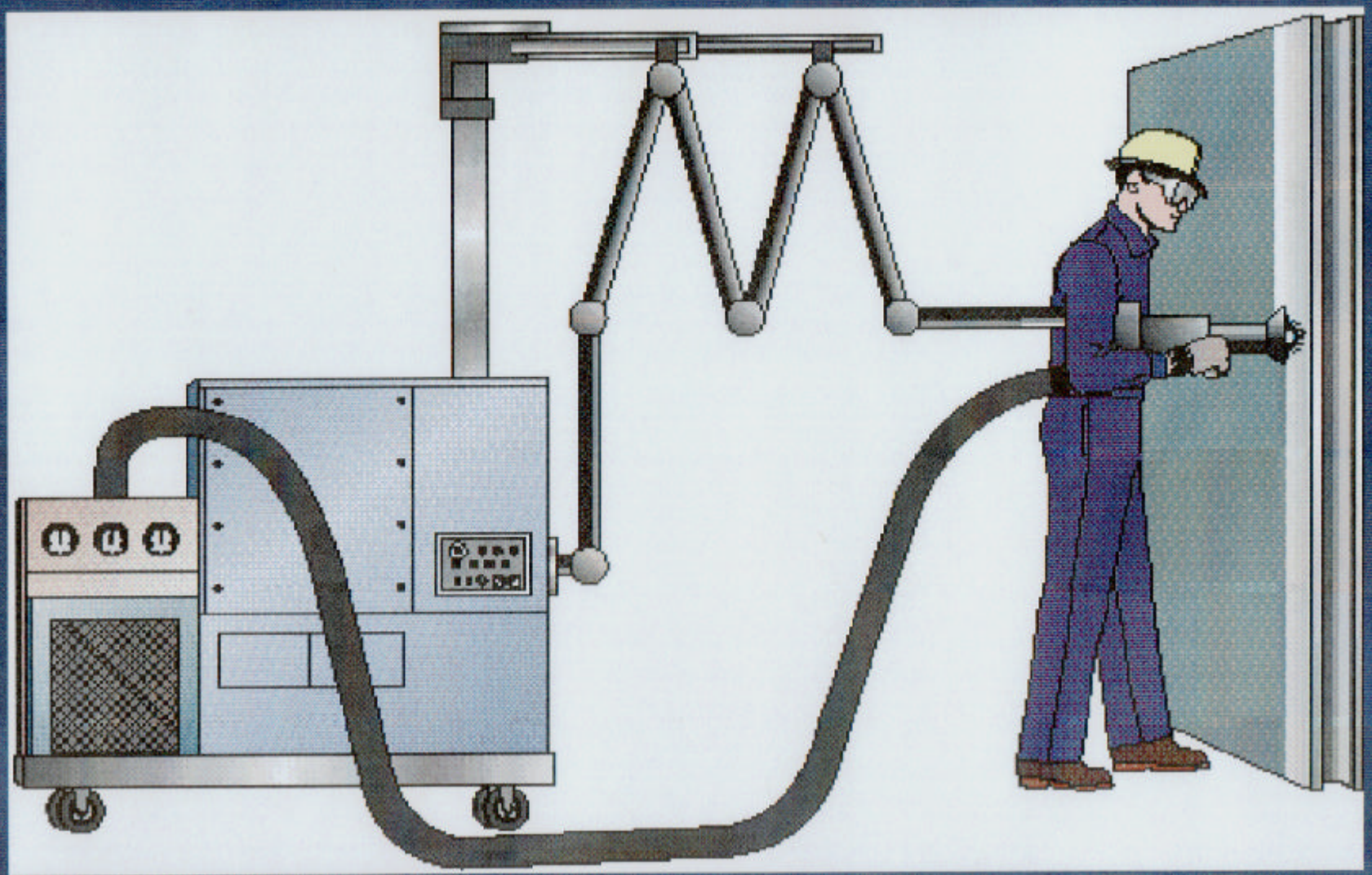
Hand-Held Depainting System



Hand-held Nozzle (Cleaning Head)

- Example of one prototype that handles a 6 kW (average power) repetitively pulsed high energy laser beam. Weight ~12lbs.
- Size and weight can be reduced if used with lower-power laser
- "Cup" at end of nozzle can be changed for inside or outside corner work

On-line Feedback Control via Spectral Sensors

- Team: F2, Los Alamos, PSI
- Concept:
  - Laser pulses --> vaporization/ionization of coating; plume emits spectrum. Only takes a few nonograms of ablated material to get spectral signature
  - ID lines from coatings and substrate. Pick a few to use.
  - Use strength, etc., for input to control algorithm

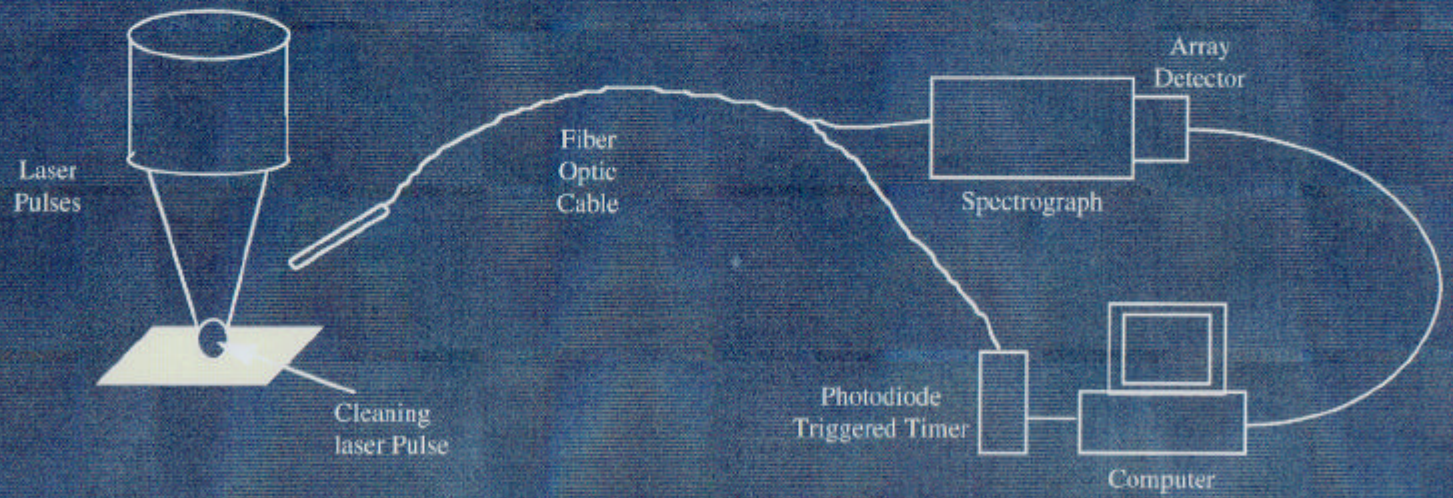


Diagram of system to be used to benchmark the atomic spectra generated by the plasma formed during laser cleaning of a surface.

- F2 has patent pending for using LIBS as a coatings removal control scheme

Lead Spectral Sensor Tests

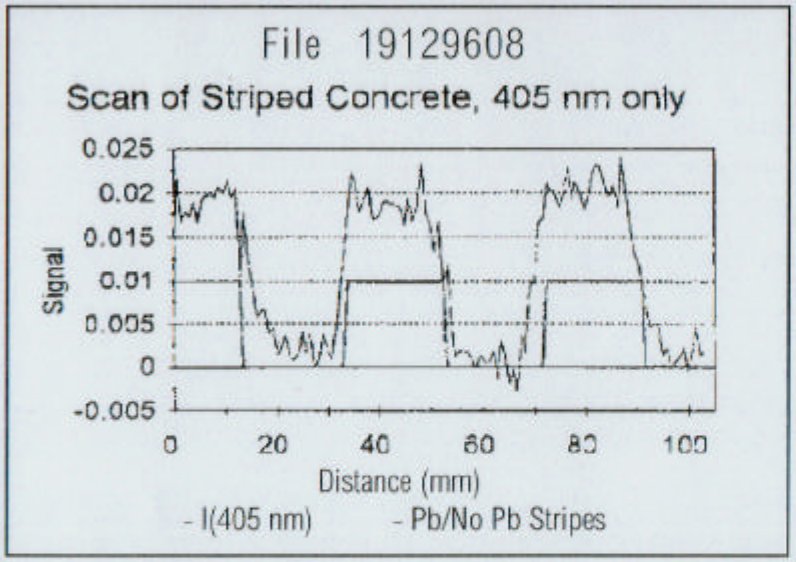


Figure 3. Signal level vs. distance across the stripped concrete sample. Also shown for comparison are the locations of the Pb and no-Pb stripes in the form of a square wave. Note that the lead signal spans the entire lead stripe into the no-lead region due to the physical dimension

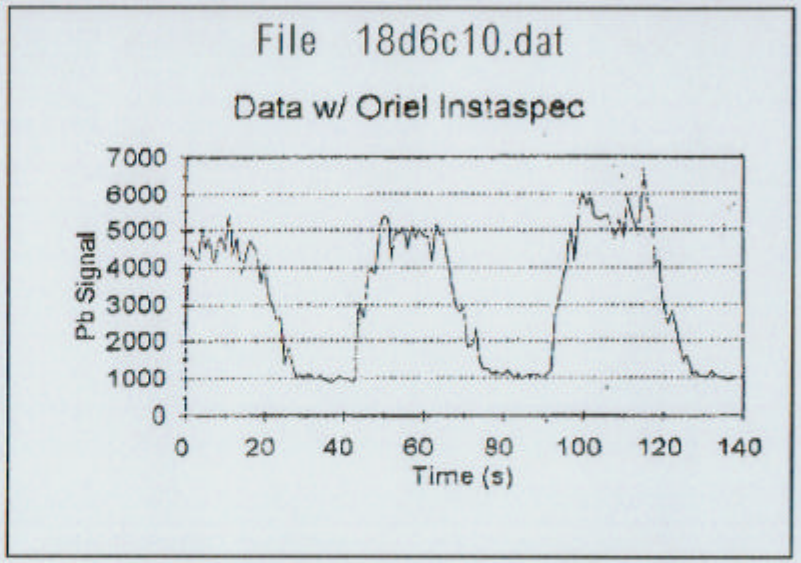


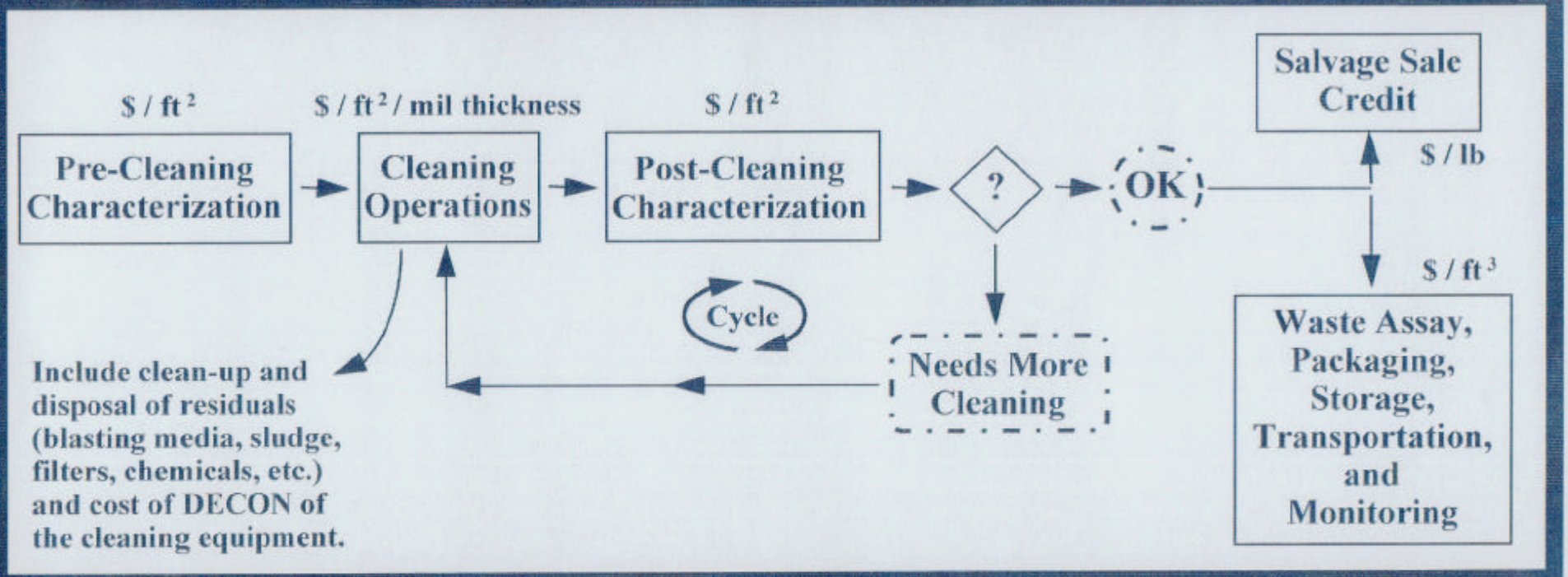
Figure 4. Lead line signal vs. time for the striped concrete sample. The sample was scanned similarly to Figure 3. This data was acquired with the Los Alamos National Lab equipment.

PSI
PHYSICAL SCIENCES INC.

Los Alamos
NATIONAL LABORATORY

Testing done at F2 Associates Inc. Dec. 1996

Simplified Flowchart of Elements of the Total D & D Process



← Total process consisting of several process elements →

Look at the entire process, not just the "Cleaning Operations" box.

What can be done in "Cleaning Operations" to save time, money, and worker exposure in the entire process?

HCET Testing & EERC Cost Model

- The DOE is funding the HCET (Hemispheric Center for Environmental Technologies), Florida International University, to conduct monitored, standardized tests of various D&D technologies.

  Contact: Mr. Richard Burton, Industrial Liaison, (305) 348-1697

- To be able to compare 'apples to apples' for different decoating technologies, DOE FETC Morgantown has funded the EERC (Energy & Environmental Research Center), University of North Dakota, to develop a comprehensive cost/benefit model.

  Contact: Mr. Ames Grisanti, (701) 777-5158

F2 & Other DOE Projects

The work at F2 brings together several DOE-funded activities:

- F2's "Laser Based Coatings Removal" contract
- Redzone's ROSIE Robot work
- PSI's Spectral Sensor work (+ Los Alamos input)
- EERC, University of North Dakota Cost/Benefits models
- SERDP (DoD, EPA, DOE) on LCCRS (laser loan, for ROSIE)

Commercialization

System

I. Small Parts Decoating

II. Large Parts, Fixed Robotic

III. Mobile Robotic

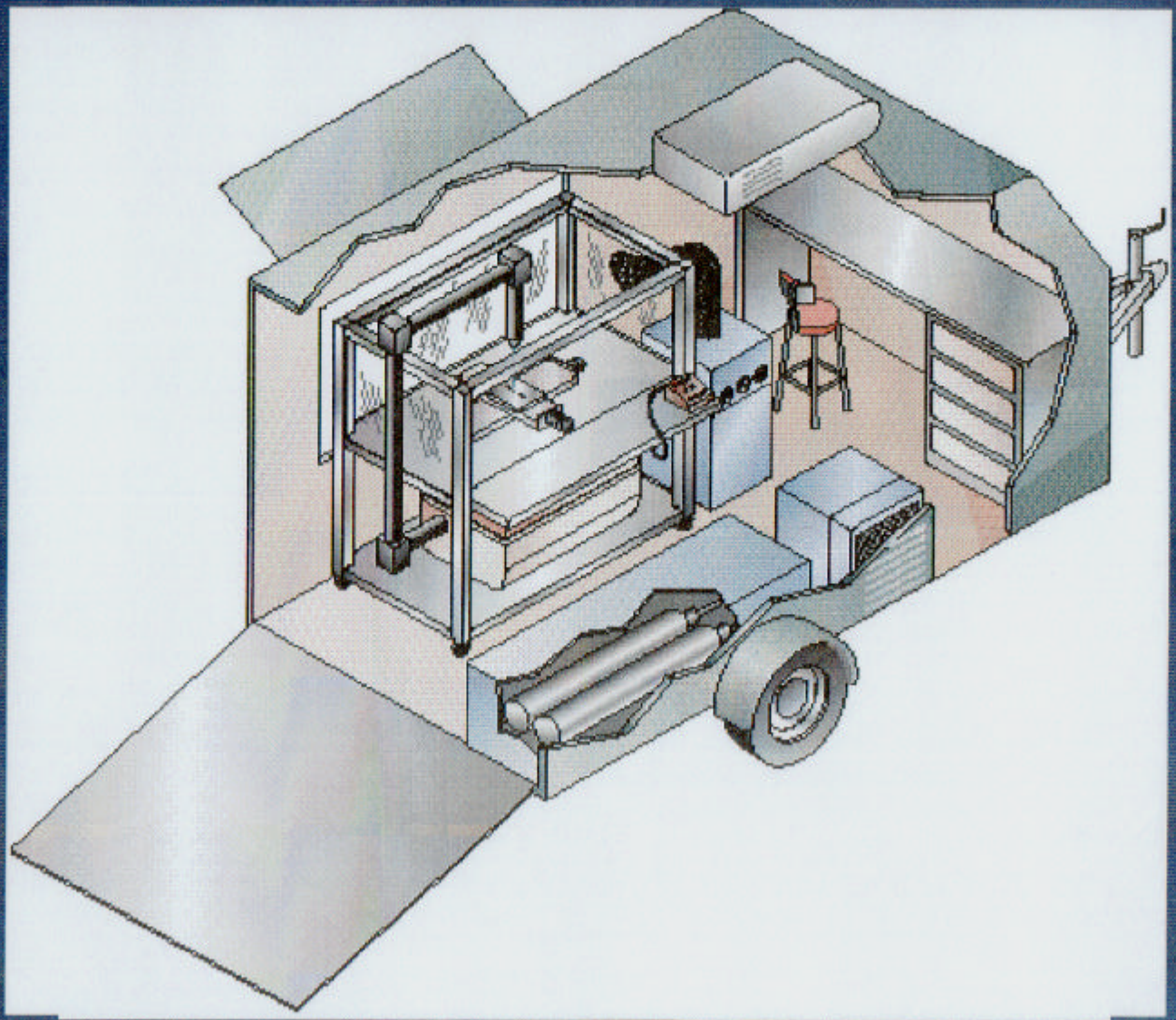
IV. Hand-held Cleaning Heads

F2 Actions

- In negotiations with GE
- Beginning negotiations with others
- LCCRS to go to NDCEE for showcase DEMVAL
- DOE Paducah?
- "X-Change`97," etc.
- Nuclear Power Plant D&D
- Bridge depainting (lead paint); CCC
- Boat depainting (lead paint)
- Full aircraft depainting (Boeing, M-D, Lockheed)
- Nuclear Power Plant D&D
- McDonnell Douglas, Northrop, etc. for aircraft
- Bridge depainting (CCC)
- Boat depainting

F2 Teaming agreement with International Nuclear Services and D&D firm, signed 9/97
F2 alliance with laser supplier
F2 literature, magazine ads, & trade-show displays
Investor interest/$s
Trade Show demo unit (next page) forthcoming mobile

Parts Cleaning Trailer



Summary

- F2 is not interested in being only a R&D firm.
- F2's goal is development of commercial product lines: Applied R&D -> full-scale prototypes, production and sales by F2

F2 sincerely thanks DOE FETC for continued support!